Reply

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Chou et al. (2002, hereinafter CLH) argue in their comment that the way in which Lin et al. (2002) analyzed the Clouds and the Earth's Radiant Energy System (CERES) data (Wielicki et al. 1996) is not appropriate. The analysis in the Lin et al. paper exactly followed the original iris idea, as presented by Lindzen et al. (2001, hereinafter LCH), yet obtained significantly different results. We have repeated the analysis with some additional thresholds as illustrated in the CLH comment, and our basic conclusion remains: the difference between the net radiative fluxes of the cloudy-moist and clear-moist regions should be small. Thus, the radiative forcing resulting from a change in tropical high cloud amount is still about 1/10 of that found in LCH. Fu et al. (2002) draw a similar conclusion using a radiation model to compute the fluxes for each region.

The key point to remember is that the albedo and longwave flux *both* depend on the population of clouds chosen. If we change the definition of the cloudy-moist region, as suggested by CLH, then the area coverage, albedo, and longwave (LW) flux will all change. Figure 1 shows the temperature and albedo response, as obtained from the CERES Earth Radiation Budget Experiment (ERBE)–like data, by varying the threshold brightness temperature T_b value to include progressively more of the high (thinner) clouds in the cloudy-moist region. Our original result is the solid black curve labeled 10% (for cloudy-moist area coverage). The threshold is progressively changed until 40% of the tropical ocean falls within the cloudy-moist region. Whatever threshold is used, the temperature response is much smaller than that suggested by LCH, and the albedo response is larger. In some of these cases a cooling effect is observed, but it is 5–10 times smaller than the iris effect postulated by LCH.

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Most simple T_b thresholds mix water and ice clouds and thick and thin clouds. A more rigorous way to examine a possible iris effect is to use cloud physical properties to define the various regions. Examination of the CERES single scanner footprint top-of-atmosphere/surface fluxes and clouds (SSF) product, which provides collocated fluxes and cloud property data, provides a way to do this. For the cloudy-moist region, Table 1 compares the radiative fluxes used by LCH with those obtained by Lin et al. from the T_b threshold and with those from the SSF when CERES footprints with a retrieved cloud temperature colder than 258 K are selected. This includes both thick and thin cirrus, unlike the $T_b < 260$ K criterion. The SSF area coverage matches that suggested by LCH, but the radiative properties are very different. In particular, the LW flux found by choosing footprints containing cold clouds is 53.8 W m^{-2} higher than that of LCH (which they obtained as a residual calculation from the ERBE tropical mean radiative properties after specifying the radiative properties of the other regions). The albedo of these clouds is also higher than LCH by 0.05, a change of approximately 20 W m^{-2} for an average tropical insolation of 400 W m^{-2}. Thus, as in Lin et al. the observed CERES net radiation for the cloudy-moist region differs from the LCH value by more than 70 W m^{-2}.

In summary, if more (thinner) high tropical clouds are included in the cloudy-moist region, not only does the albedo go down, but the longwave flux from the region also increases. Thus, the net radiation difference

TABLE 1. Radiative properties of tropical cloudy-moist region. Here SW denotes shortwave.

	Area coverage	SW albedo	LW flux (W m^{-2})
LCH ($T_b < 260$ K used as index only)	0.22	0.349	137.7
Lin et al. ($T_b < 260$ K)	0.1	0.510	154.8
SSF ($T_{cloud} < 258$ K)	0.22	0.396	191.5

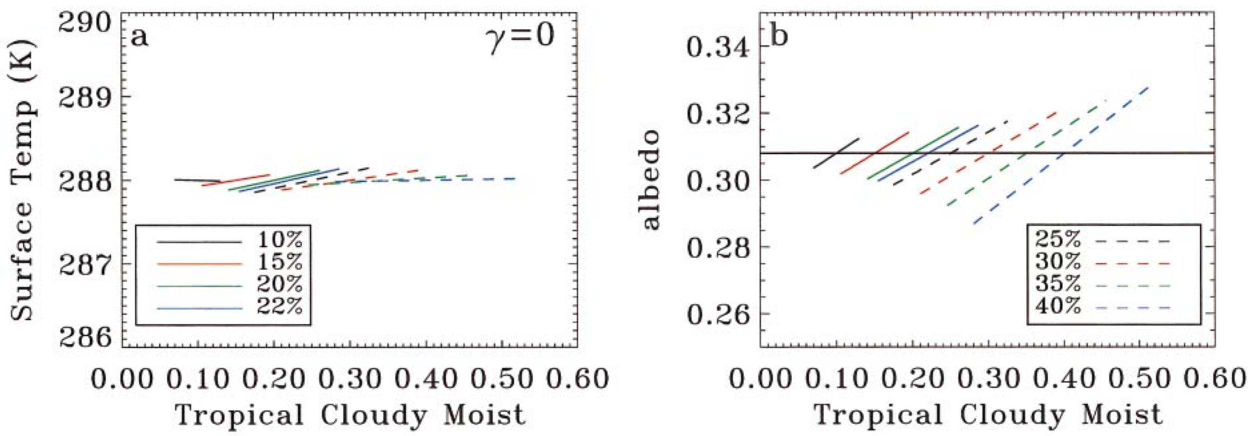

FIG. 1. The response of (a) surface temperature and (b) albedo, as a function of the area coverage of the tropical cloudy-moist region. The original Lin et al. (2002) value is labeled 10%. Increasing area coverage is obtained by increasing the threshold T_b.

between the various regions of the LCH model is small, and the conclusions of Lin et al. (2002) stand.

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